भारतीय मानक
Indian Standard

IS 10137 : 2015
(Reaffirmed 2020)

उत्पलवों एवं ऊर्जा क्षयकारकों के चुनाव के मार्गदर्शी सिद्धांत

(पहला पुनरीक्षण)

Guidelines for Selection of Spillways and Energy Dissipators

(First Revision)

ICS 93.160

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December 2015 **Price Group 7**

Dams and Spillways Sectional Committee WRD 09

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of India Standards, after the draft finalized by the Dams and Spillways Sectional Committee had been approved by the Water Resources Division Council.

Spillways are provided as integral part of a dam or as an auxiliary structure constructed separate from the main dam to release surplus flood waters which are in excess of the storage space in the reservoir as provided in the operation plan and must be passed downstream. The primary function of spillways is to release surplus water in conjunction with other discharging devices from the reservoir, in order to prevent rise of water level above a specified level in the reservoir to avoid unwanted submergence upstream or consequent overtopping and possible failure of the dam. Thus, spillways work as safety valves for a dam and the adjoining country side.

In case of spillways negotiating large drops, the water discharged over the spillway generally attains a velocity which may be much higher than the safe flow conditions downstream and may cause serious scour and erosion of river bed downstream. To dissipate this excessive energy and to establish safe flow conditions in the downstream of a dam spillway, energy dissipators are used as remedial devices.

This standard was first issued in 1982. The present revision incorporates additional types of spillways such as Vortex drop spillway, Orifice spillway, Stepped spillway, Duckbill spillway and labyrinth spillway. This revision also covers two stage Energy dissipators whose design is non-conventional as it involves a combination of two energy dissipators.

Indian Standard

GUIDELINES FOR SELECTION OF SPILLWAYS AND ENERGY DISSIPATORS

(First Revision)

1 SCOPE

1.1 This standard lays down guidelines for selection of types of spillways and energy dissipators.

2 REFERENCES

The following standards contain provisions which, through reference in this text constitute provisions of this standard. At the time of publication the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard indicated below.

IS No.	*Title*
4410 (Part 9) : 1982	Glossary of terms relating to river valley projects: Part 9 Spillways and siphons (*first revision*)
4997 : 1968	Criteria for design of hydraulic jump type stilling basins with horizontal and sloping apron
5186 : 1994	Design of chute and side channel spillways — Criteria (*first revision*)
6934 : 1998	Recommendations for hydraulic design of high ogee overflow spillways (*first revision*)
7365 : 2010	Criteria for hydraulic design of bucket type energy dissipators (*second revision*)
11485 : 1985	Criteria for hydraulic design of sluices in concrete and masonry dams
13048 : 1991	Recommendations for hydraulic design of duck bill spillways

3 TERMINOLOGY

3.1 For the purpose of this standard the definitions given in IS 4410 (Part 9) shall apply.

4 TYPE OF SPILLWAYS

4.1 Ogee Spillway (*see* Fig. 1)

This type comprises a structure whose crest is S-shaped. The shape conforms closely with the profile of the aerated lower nappe falling from a sharp crested weir. The profile of the crest may be made either broader or sharper than the nappe. A broader profile helps in the stability of the crest and gives a stable, cavitation-free flow, but reducing thereby the coefficient of discharge. A sharper crest increases the coefficient of discharge, but may produce sub-atmospheric pressures. This type of spillway may be gated or ungated. For detailed design consideration IS 6934 may be referred.

4.2 Chute Spillway (*see* Fig. 2)

In this arrangement, water is conveyed from the reservoir to the river or to another natural drainage below the dam through an excavated or built-up channel trough with

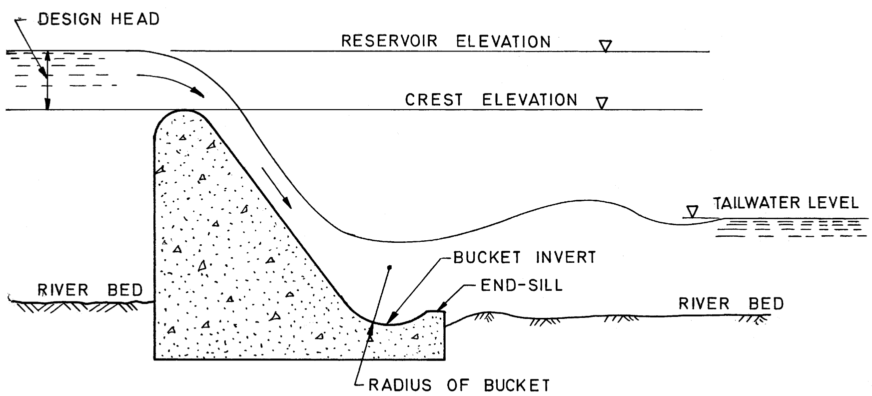


FIG. 1 OGEE SPILLWAY

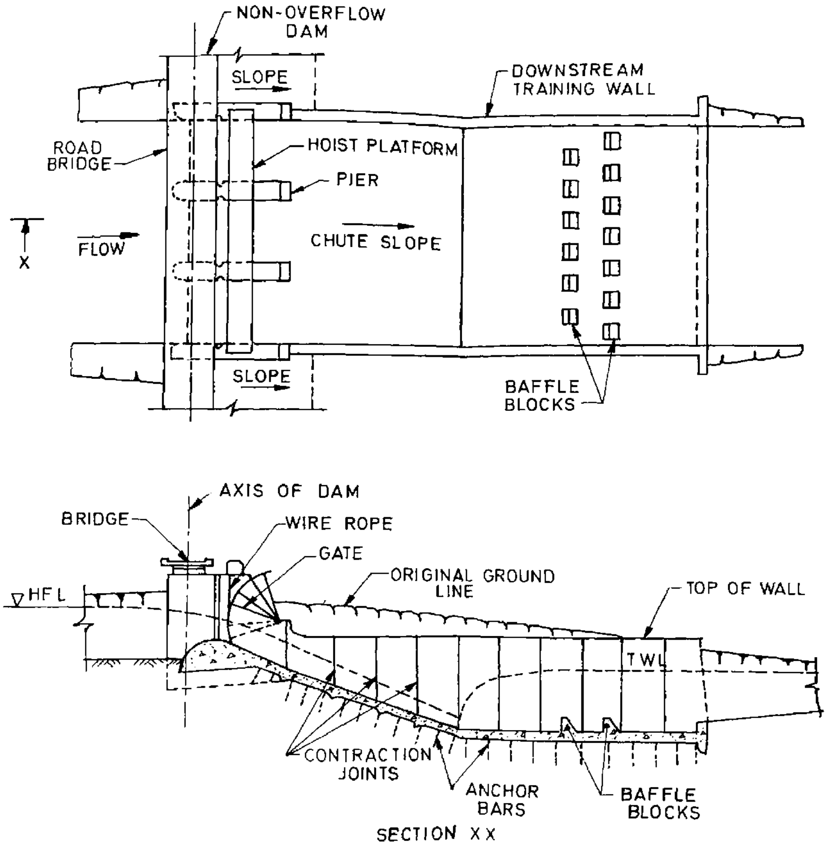


FIG. 2 CHUTE SPILLWAY

fairly steep slope. It may be located either along a dam abutment or through a saddle in the rim of the reservoir. Sometimes, steps are provided in the channel (cascade spillway) to help in dissipation of energy. For detailed design consideration IS 5186 may be referred.

4.3 Side Channel Spillway (*see* Fig. 3)

Here the crest is placed parallel to the discharge channel. Flow into the side channel might enter on only one side of the trough in the case of steep hillside locations, or on both sides and over the end of the trough if it is located on a knoll or gently sloping abutment. Discharge characteristics are similar to an ordinary overflow weir, except that at a high discharge the crest may be partly submerged. For detailed design consideration IS 5186 may be referred.

4.4 Shaft Spillway (*see* Fig. 4)

In this type, water enters over a horizontal circular crest and drops through a vertical flaring tunnel or sloping shaft, and then flows downstream through a nearly horizontal conduit or tunnel. This is also known as drop outlet or morning glory spillway. The crest may be ogee type or flat.

4.5 Siphon Spillway (*see* Fig. 5)

It is a closed conduit system formed in the shape of an inverted U-tube, positioned so that the inside of the bend of the upper passageway is at the normal storage level of the reservoir. The initial discharges from the siphon spillway are just like the discharges over a weir. After the air in the bend over the crest is exhausted, the water is discharged through siphoned action.

4.6 Overfall Spillway (*see* Fig. 6)

It is a weir in which the flow falls freely from the crest. The crest is sometimes extended in the form of an overhanging lip to direct the small discharges away from the face of the overfall section. Care should be taken of the spray that results from aeration of the jet or from its impact. It can cause damage to the countryside and may adversely affect nearby electrical installations. The underside of the nappe is ventilated sufficiently to prevent a pulsating, fluctuating jet. Where no artificial protection is provided at the base of overfall, scour occurs and a deep plunge pool is formed.

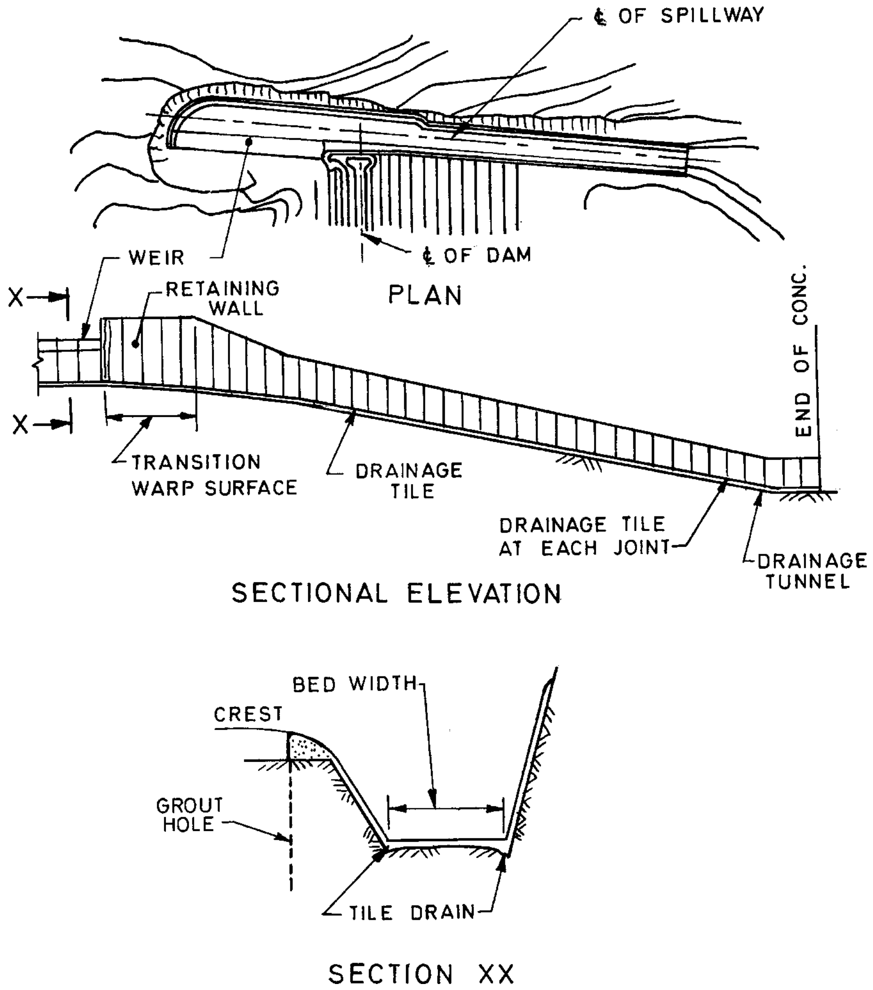


FIG. 3 SIDE CHANNEL SPILLWAY

4.7 Barrage Type Spillway (*see* Fig. 7)

It consists of a series of gates separated by piers with floors in between the piers to prevent scour and undermining. The crest is not high above the bed level and the flow may generally be submerged.

4.8 Tunnel Conduit Spillway (*see* Fig. 8)

Where a closed channel is used to convey the discharge, the spillway is known as a tunnel or conduit spillway. The tunnel may be horizontal or inclined, through the earth or rock. Control and overflow crest may be of ogee type. Tunnels are designed to run partly full.

4.9 Saddle Spillway (*see* Fig. 9)

In some basins formed by a dam, there may be one or more natural depressions for providing spillway. They are sometimes preferred for locating main spillway or emergency or auxiliary spillways. A site which has a saddle is very desirable and economical, if the saddle is suitable for locating the spillway.

4.10 Fuse Plug

It may be a simple earth bank, flash board or other device designed to fail when overtopped. Such plugs may be used where the sudden release of a considerable volume of water is both safe and not over destructive to the environment.

4.11 Sluice Spillway (*see* Fig. 10)

The use of large bottom openings as spillways is a relatively modern innovation following the greater reliance on the safety and operation of modern control gates under high pressure. A distinct advantage of this type of spillway is that provision can usually be made for its use for the passage of floods during construction. One disadvantage is that, once built, its capacity is definite whereas the forecasting of floods is still indefinite. A second disadvantage is that a single outlet may be blocked by flood debris, especially where in flow timber does not float. For detailed design consideration IS 11485 may be referred.

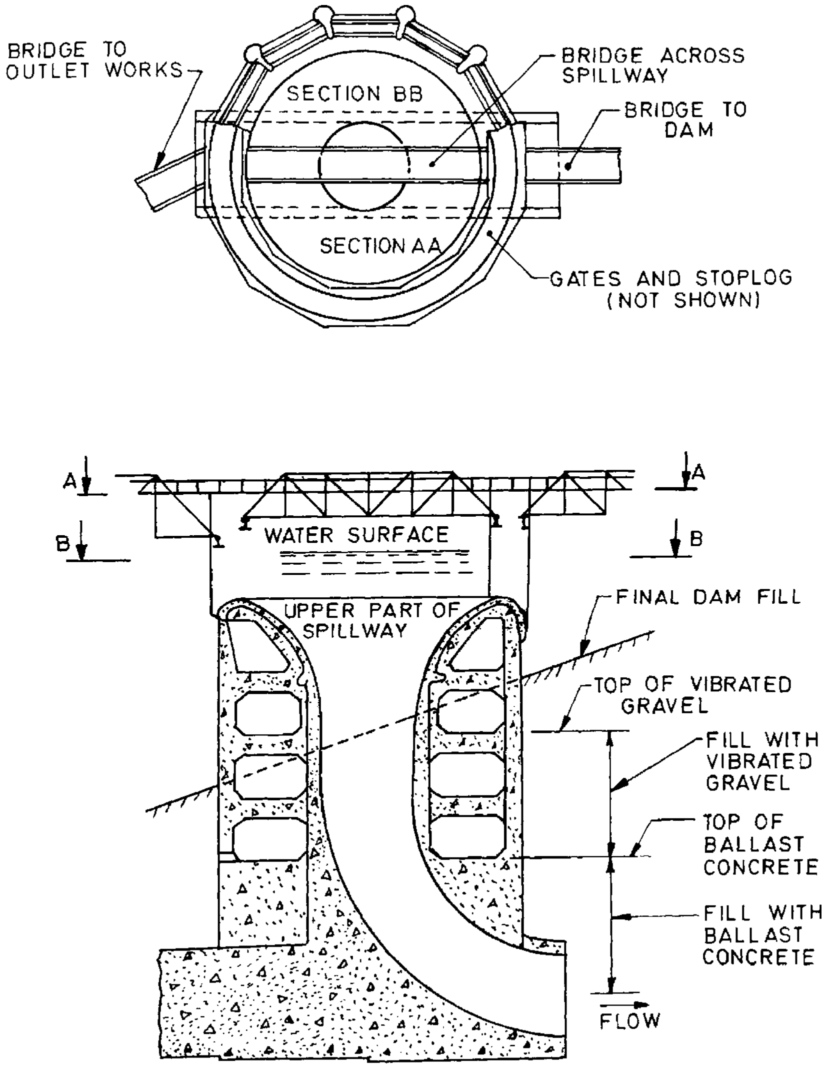


FIG. 4 SHAFT SPILLWAY

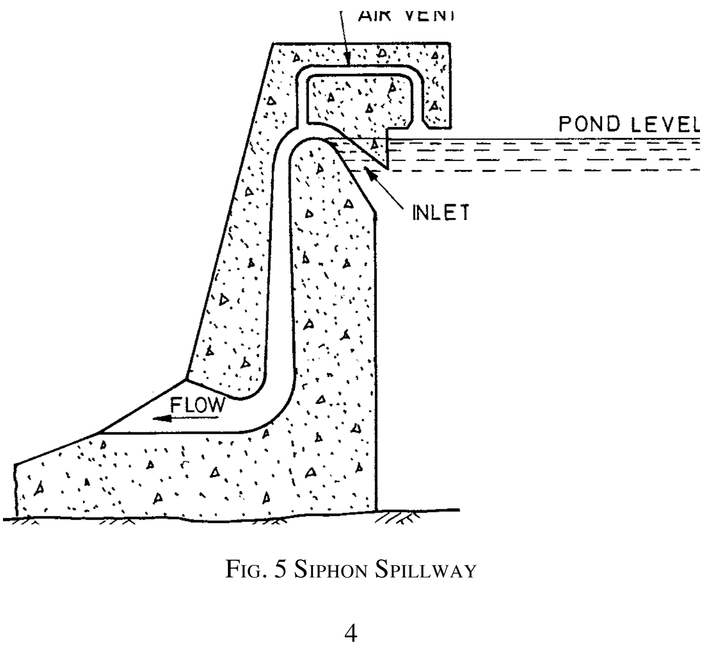


FIG. 5 SIPHON SPILLWAY

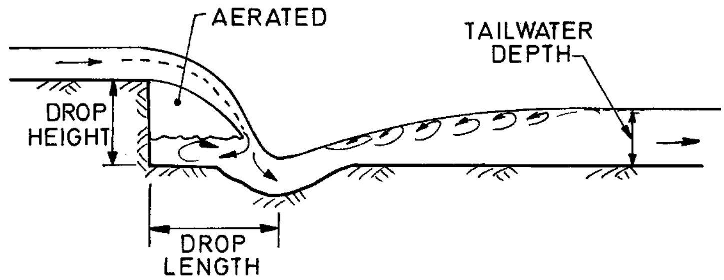


FIG. 6 OVERFALL SPILLWAY

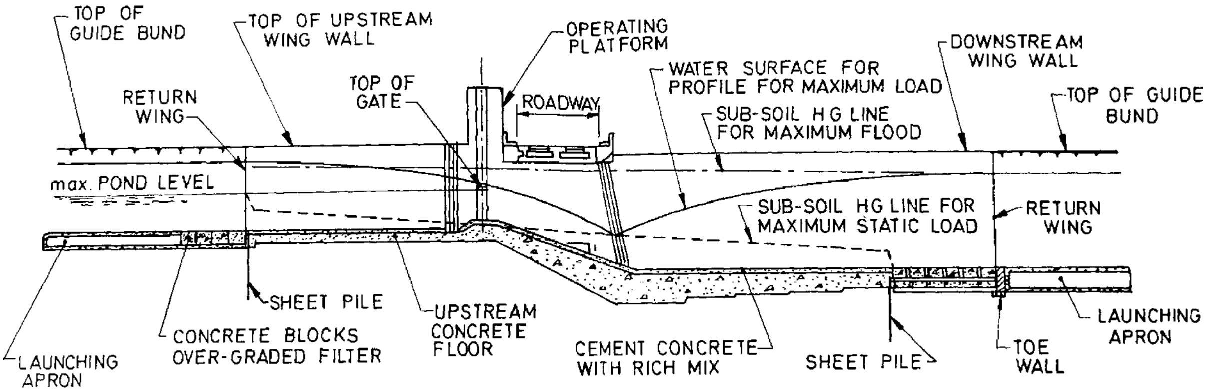


FIG. 7 BARRAGE TYPE SPILLWAY

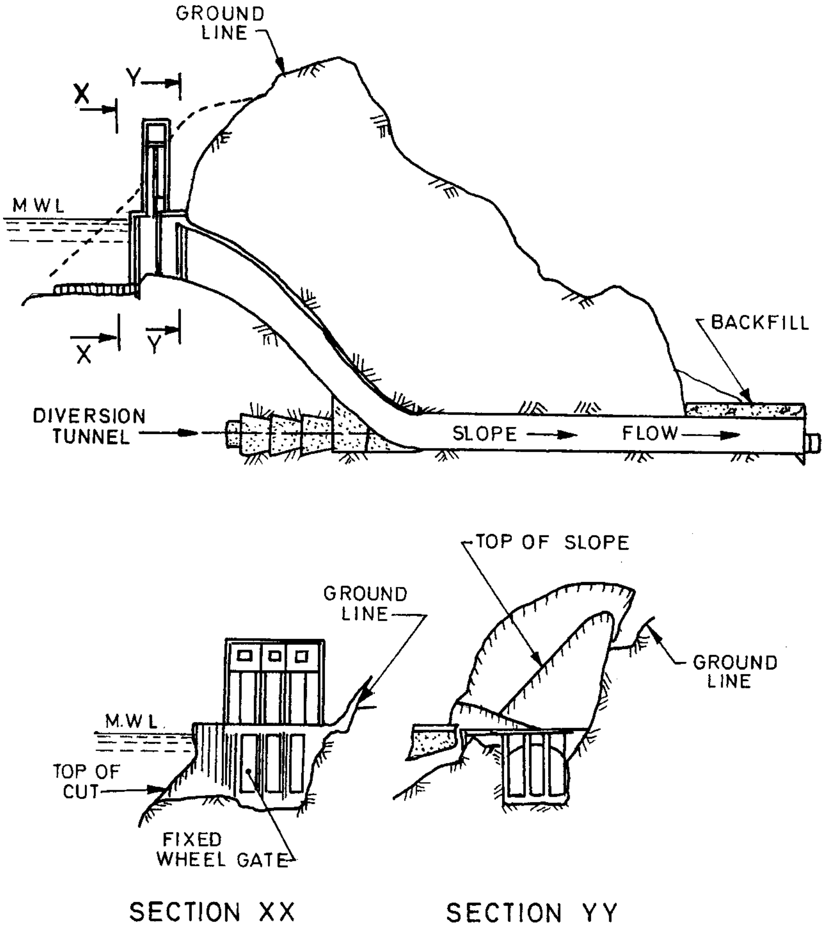


FIG. 8 TUNNEL CONDUIT SUBWAY

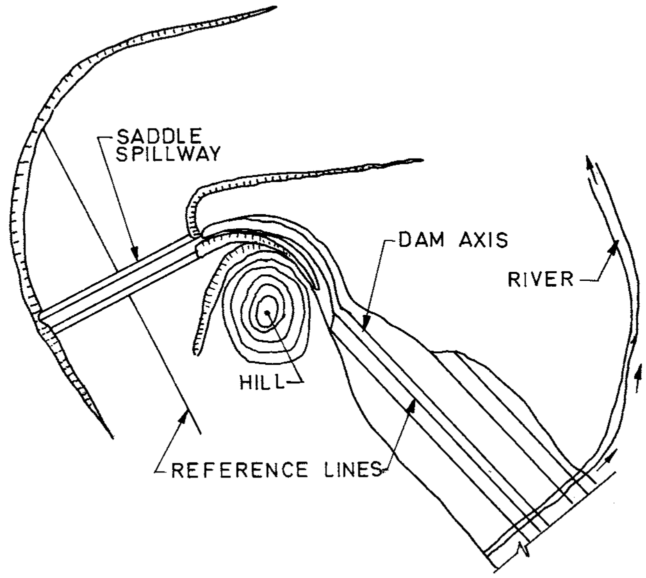


FIG. 9 SADDLE SPILLWAY

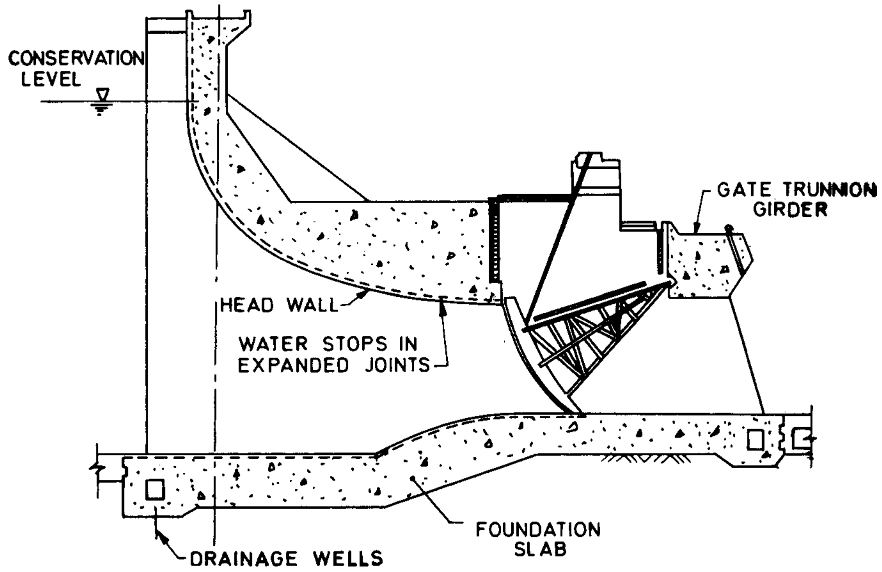


FIG. 10 SLUICE SPILLWAY

4.12 Vortex Drop Spillway (Tangential Intake) (*see* **Fig. 11**)

In this type water is conveyed as a swirling flow down a vertical or near- vertical drop shaft. There are several intake configurations used to produce swirling flows. The five broad categories are: (a) Circular, (b) Scroll, (c) Spiral, (d) Tangential, and (e) Symphonic. Among these, circular and scroll types of intakes have sub-critical approach flow conditions. Spiral and tangential have supercritical approach flow conditions. Symphonic intakes are uncommon due to their complex geometry. The circular and scroll types of intakes are generally used for smaller discharges up to 2 cumec in storm sewer system, whereas the tangential intakes are used in spillways. The approach flow enters a vortex drop spillway at the top of the drop shaft and then swirls down the drop shaft. There are various approach configurations and this imparts an angular motion to the flow which then enters the drop shaft as a swirling annular jet with an air core at the centre of the drop shaft. As the flow passes down the drop shaft, its vertical velocity component increases, the swirl attenuates and the flow direction gradually approaches the vertical. The flow continues to hug the drop shaft wall even for a relatively low flow with a small

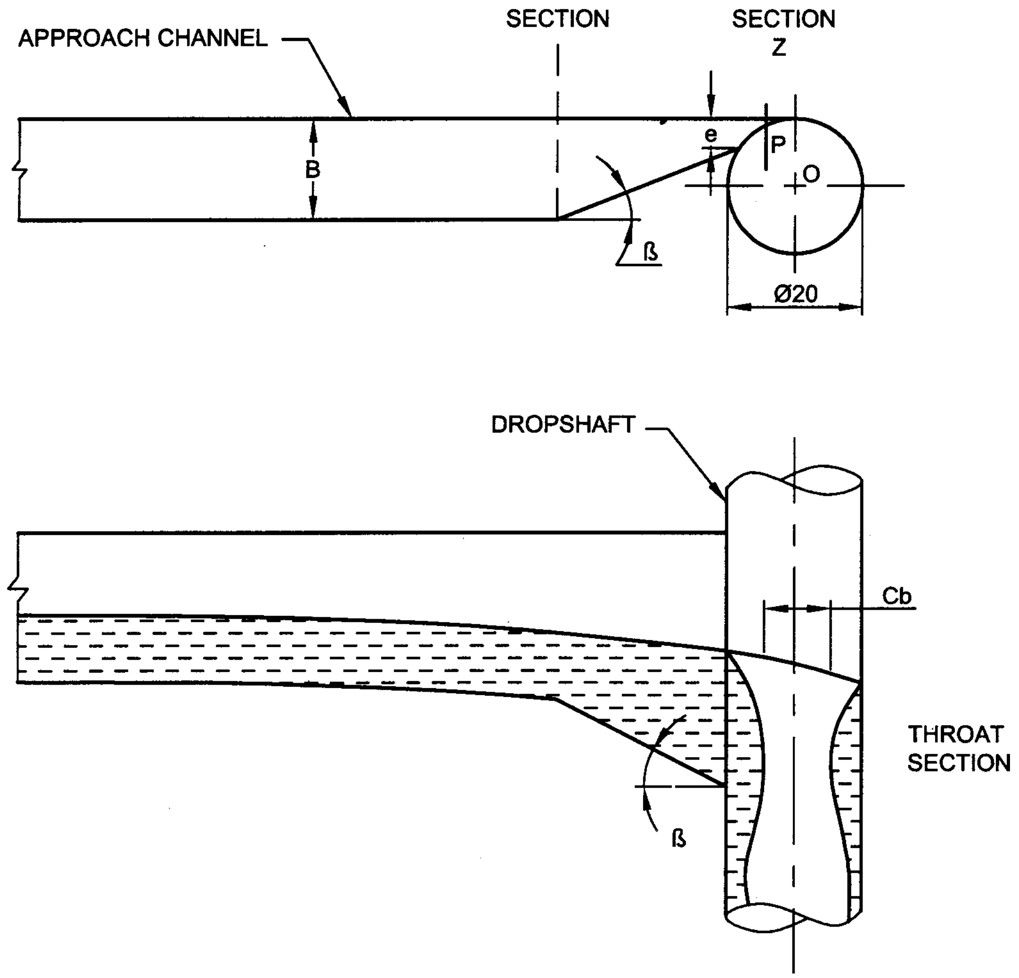


FIG. 11 VORTEX DROP SPILLWAY (TRANGENTIAL INTAKE)

tangential velocity component. The swirling flow along a drop shaft wall results in considerable dissipation of the flow energy.

4.13 Orifice Spillway (*see* Fig. 12)

The breast wall provided on overflow spillway forms an orifice. In combination with the radial gates on spillway crest it provides advantage of reducing the height of the spillway structure and also minimizing the size of the radial gates resulting in the increased flushing efficiency. This kind of spillway has been evolved from the concept of sluice spillways. Some times the sluice spillways are difficult to be accommodated structurally in the available width because of their large size. The breast wall spillways are increasingly being adopted on the run-of-the river schemes on the rivers carrying large amount of sediments in the Himalayan regions because of their suitability to discharge both flood and sediments. Figure 12 shows a typical orifice spillway.

4.14 Stepped Spillway (*see* Fig. 13)

Stepped spillway is an open spillway with continuous steps of various sizes from crest to the toe of the spillway. The steps increase significantly the rate of energy dissipation along the chute and reduce the size of the energy dissipator downstream. The hydraulics of stepped spillway is complex than the conventional spillway due to two flow regimes, that is nappe flow and skimming flow. Generally, the application of stepped spillway is limited to dam heights upto 40 m with discharge intensity upto 30 cumec/m.

4.15 Duck Bill Spillway (*see* Fig. 14)

This is a spillway, with rectangular layout projections into the reservoir comprising three straight overflow lengths intersecting at right angles. The layout could be trapezoidal in which case the corner angles will be other than 90°. The flow from the three reaches of the spillway interacts in the trough portion and is further conveyed through a discharge channel on to a terminal

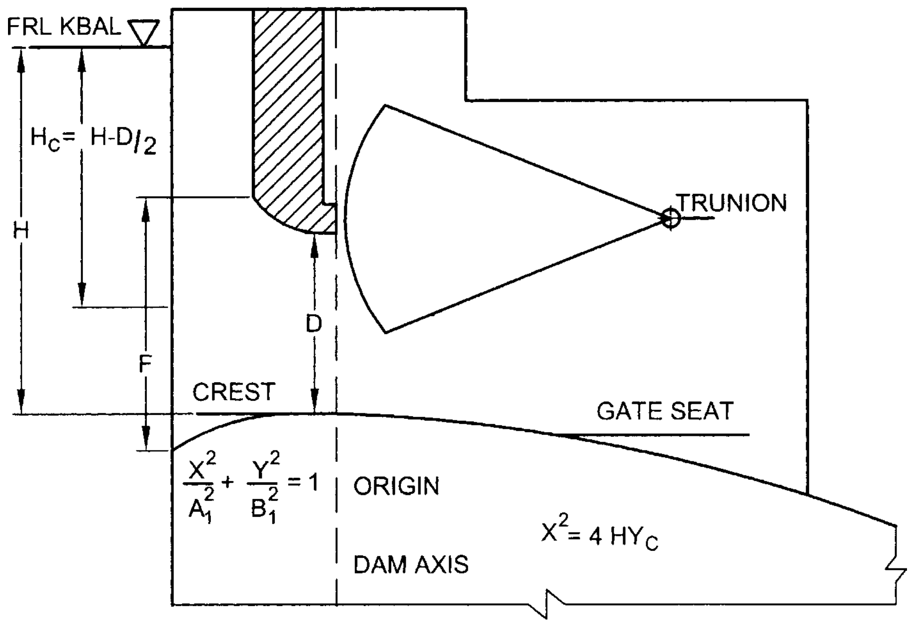


FIG. 12 ORIFICE SPILLWAY

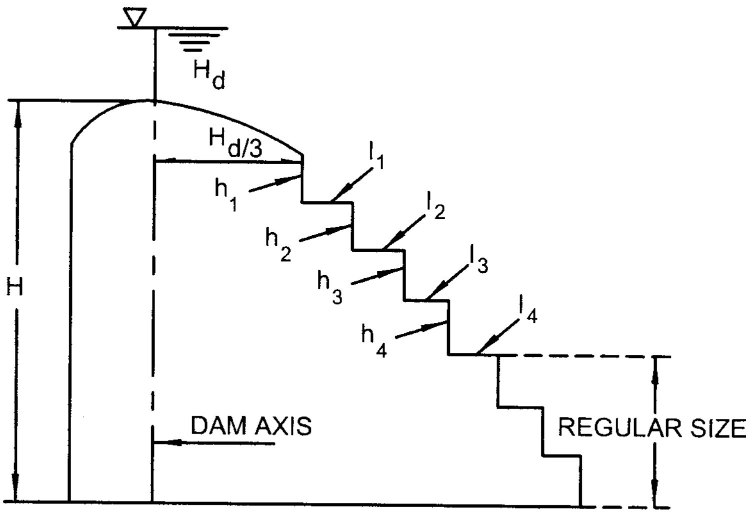


FIG. 13 STEPPED SPILLWAYS

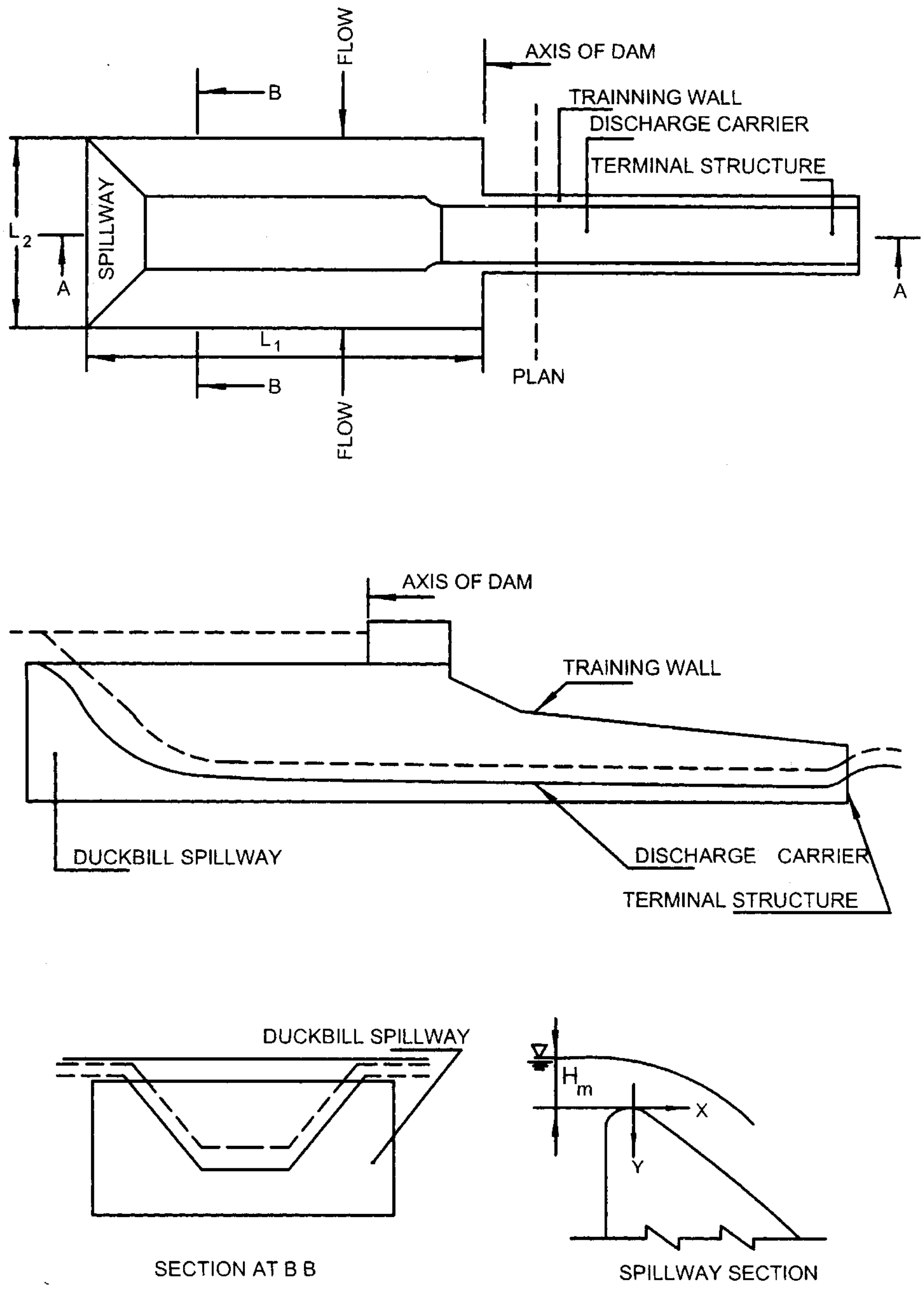


FIG. 14 DUCKBILL SPILLWAY

structure provided for energy dissipation. For detailed design consideration IS 13048 may be referred.

4.16 Labyrinth Spillway (*see* Fig. 15)

Unusual spillway shapes (in plan) are often resorted to when it is desirable to increase the effective spillway length. Labyrinth spillway is one such spillway where there is an increase in the spillway crest length without an associated increase in the width of structure. The labyrinth weir consists of a series of relatively slender walls having a repetitive plan form, shaped generally triangular or trapezoidal with a vertical upstream face. The increased crest length allows the passage of greater discharges for a given width and operating head. These are particularly suited to sites where the spillway width and upstream water surface are limited and larger discharging capacities are required.

5 FACTORS AFFECTING SELECTION OF SPILLWAYS

5.1 General Considerations

5.1.1 *Safety Considerations Consistent with Economy*

Spillway structures add substantially to the cost of a dam. In selecting a type of spillway for a dam, economy in cost should not be the only criterion. The cost of

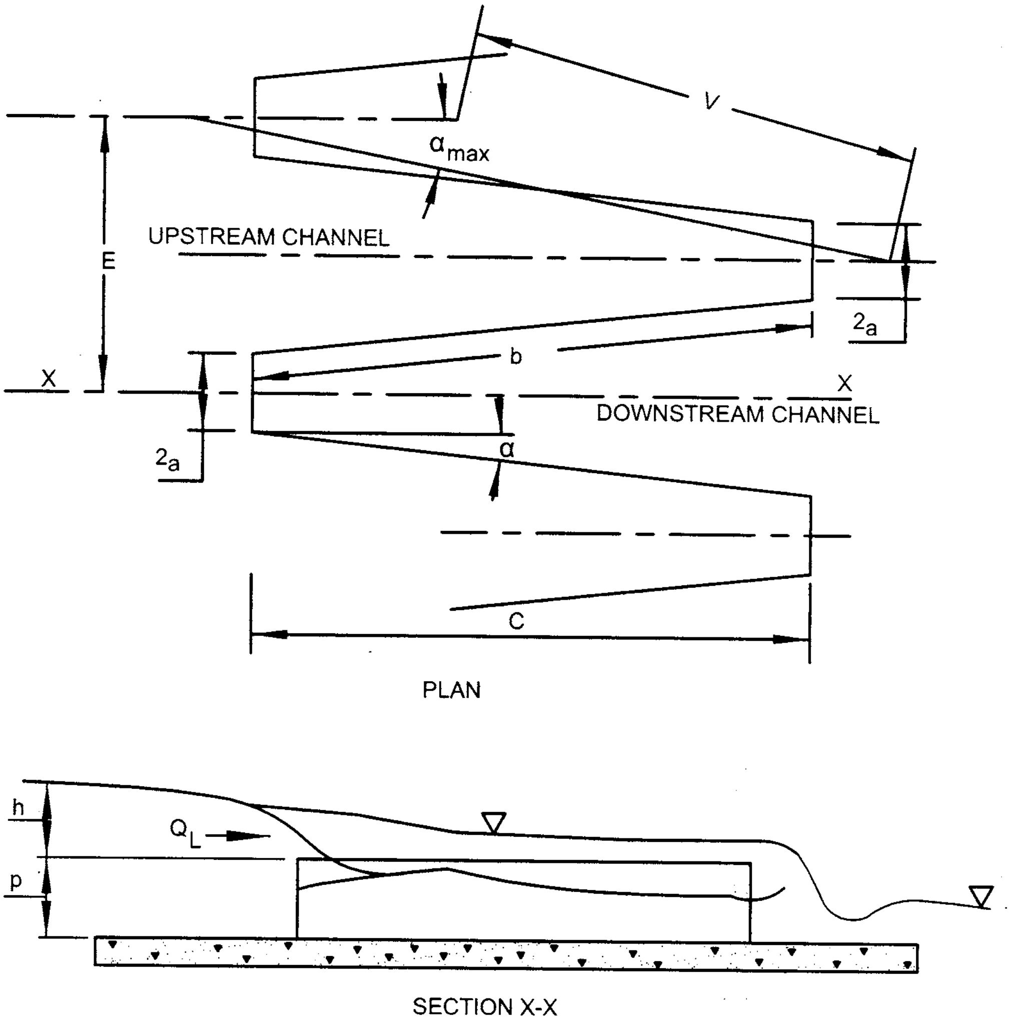


FIG. 15 LABYRINTH SPILLWAYS

spillway must be weighed in the light of safety required below the dam.

5.1.2 *Hydrological and Site Conditions*

The type of spillway to be chosen shall depend on:

a) inflow flood,
b) availability of tail channel, its capacity and flow hydraulics,
c) power house, tail race and other structures downstream, and
d) topography.

5.1.3 *Type of Dam*

This is one of the main factors in deciding the type of spillway. For earthfill and rockfill dams, chute and ogee spillways are commonly provided, whereas for an arch dam a free fall or morning glory or chute or tunnel spillway is more appropriate. Gravity dams are mostly provided with ogee spillways.

5.1.4 *Purpose of Dam and Operating Conditions*

The purpose of the dam mainly determines whether the dam is to be provided with a gated spillway or a non-gated one. A diversion dam can have a fixed level crest that is non-gated crest.

5.1.5 *Conditions Downstream of a Dam*

The rise in the downstream level in heavy floods and its consequences need careful consideration. Certain spillways alter greatly the shape of the hydrograph downstream of a dam. The discharges from a siphon spillway may have surges and break-ups as priming and depriming occurs. This gives rise to the wave travelling downstream in the river, which may be detrimental to navigation and fishing and may also cause damage to population and developed areas downstream.

5.1.6 *Nature and Amount of Solid Materials Brought by the River*

Trees, floating debris, sediment in suspension, etc, affect the type of spillway to be provided. A siphon spillway cannot be successful if the inflow brings too much of floating materials. Where big trees come as floating materials, the chute or ogee spillway remains the common choice.

5.2 Specific Considerations

5.2.1 *Ogee Spillway*

a) It is most commonly used with gravity dams. However, it is also used with earth and rockfill dams with a separate gravity structure (*see* IS 6934);
b) The ogee crest can be used as control in almost all types of spillways; and
c) It has got the advantage over other spillways for its high discharging efficiency.

5.2.2 *Chute Spillway* (*see* IS 5186)

a) It can be provided on any type of foundation,
b) It is commonly used with the earth and rockfill dams, and
c) It becomes economical if earth received from spillway excavation is used in dam construction.

5.2.2.1 Following factors limit its adoption:

a) It should normally be avoided on embankments,
b) Availability of space is essential for keeping the spillway basins away from the dam paving, and
c) If it is necessary to provide too many bends in the chute because of the topography, its hydraulic performance can be adversely affected.

5.2.3 *Side Channel Spillways* (*see* IS 5186)

a) This type of spillway is preferred where a long overflow crest is desired in order to limit the intensity of discharge,
b) It is useful where the abutments are steep, and
c) It is useful where the control is desired by the narrow side channel.

5.2.3.1 The factor limiting its adoption is that this type of spillway is hydraulically less efficient.

5.2.4 *Shaft Spillway* (*Morning Glory Spillway*)

a) This can be adopted very advantageously in dam sites in narrow canyons, and
b) Minimum discharging capacity is attained at relatively low heads. This characteristic makes the spillway ideal where the maximum spillway outflow is to be limited. This characteristic becomes undesirable where a flood more than the design capacity is to be passed. So, it can be used as a service spillway in conjunction with an emergency spillway.

5.2.4.1 The factor limiting its adoption is the difficulty of air-entrainment in a shaft, which may escape in bursts causing an undesirable surging motion.

5.2.5 *Siphon Spillway*

a) Siphon spillways can be used to discharge full capacity discharges, at relatively low heads; and
b) Great advantage of this type of spillway is its positive and automatic operation without mechanical devices and moving parts.

5.2.5.1 The following factors limit the adoption of a siphon spillway:

a) It is difficult to handle flows materially greater than designed capacity, even if the reservoir head exceeds the design level;
b) Siphon spillways cannot pass debris, ice, etc;
c) There is possibility of clogging of the siphon passage way and breaking of siphon vents with logs and debris;
d) In cold climates, there can be freezing inside the inlet and air vents of the siphon;
e) When sudden surges occur and outflow stops;
f) The structure is subject to heavy vibrations during its operation needing strong foundations; and
g) Siphons cannot be normally used for vacuum heads higher than 8 m and there is danger of cavitation damage.

5.2.6 *Overfall or Free Fall Spillway*

a) This is suitable for arch dams or dams with downstream vertical faces; and
b) This is suitable for small drops and for passing any occasional flood.

5.2.6.1 The factor limiting its adoption is that, ordinarily, the maximum hydraulic drop from head pool to tail pool water should not exceed 20 m.

5.2.7 *Barrage Spillway*

It may be used where a temporary and small storage above the crest is required.

5.2.8 *Tunnel or Conduit Spillway*

This type is generally suitable for dams in narrow valleys, where overflow spillways cannot be located

without risk and good sites are not available for a saddle spillway. In such cases, diversion tunnels used for construction can be modified to work as tunnel spillways. In case of embankment dams, diversion tunnels used during construction may usefully be adopted. Where there is danger to open channels from snow or rock slides, tunnel spillways are useful.

5.2.9 *Saddle Spillway*

a) It is generally economical,
b) It facilitates construction because it is independent of the main dam construction, and
c) It can also be used as an auxiliary or emergency spillway.

5.2.10 *Fuse Plug*

a) It is provided away from the main structure, generally in a saddle, and
b) It is generally provided to handle only extraordinary floods above the capacity of main spillway, and when it is not possible to provide total surplus capacity at the main spillway. It may also be used with advantage with shaft, siphon and sluice spillways which cannot effectively handle discharges beyond the design capacity.

5.2.11 *Bottom Opening*

a) It can be adopted with advantage in case of rivers with steady flows which require and can accommodate large releases downstream, and
b) When separate outlets for release downstream may not be necessary.

5.2.11.1 The following factors limit the adoption of the bottom opening spillway:

a) It can be effectively used only with the provision of an emergency spillway, and
b) There is a possibility of the outlet being blocked by floating debris under unfavourable circumstances.

5.2.12 *Vortex Drop*

It is a special type of shaft spillway. It can be provided where topography does not permit radial inflow conditions.

5.2.13 *Orifice Spillway*

Orifice spillways are usually provided in diversion dams of run-of-river projects built on the rivers carrying lot of sediment load. They serve the dual purpose of passing floods as well as flushing of the sediment deposited in the reservoir into the river downstream.

5.2.14 *Stepped Spillway*

Use of stepped spillway is limited to discharge intensity up to 30 $m^3/s/m$.

5.2.15 *Duckbill/Labyrinth Spillway*

These spillways are particularly suited to sites where the spillway width and upstream water surface are limited and larger discharging capacities are required. This may also provide additional storage capacity in lieu of a more costly gated structure.

6 TYPES OF ENERGY DISSIPATORS

6.1 Different types of energy dissipators are listed in **6.1.1**, **6.1.2** and **6.1.3** which can be used alone or in combination of more than one, depending upon the energy to the dissipated and erosion control required downstream of a dam.

6.1.1 *Stilling Basins*

a) Hydraulic jump type stilling basins (*see* IS 4997)
   1) Horizontal apron type, and
   2) Sloping apron type.
b) Jet diffusion stilling basins:
   1) Jet diffusion stilling basin (*see* Fig. 16),
   2) Interacting jet dissipators (*see* Fig. 17),
   3) Free jet stilling basin (*see* Fig. 18),
   4) Hump stilling basin (*see* Fig. 19), and
   5) Impact stilling basin (*see* Fig. 20 and 21).

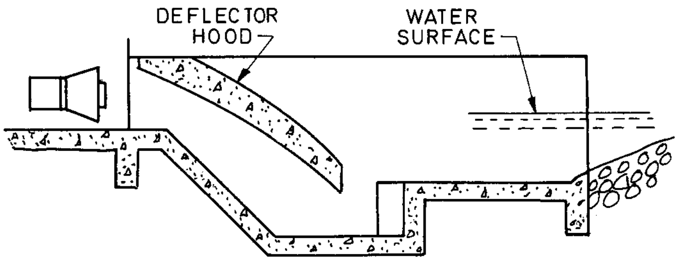
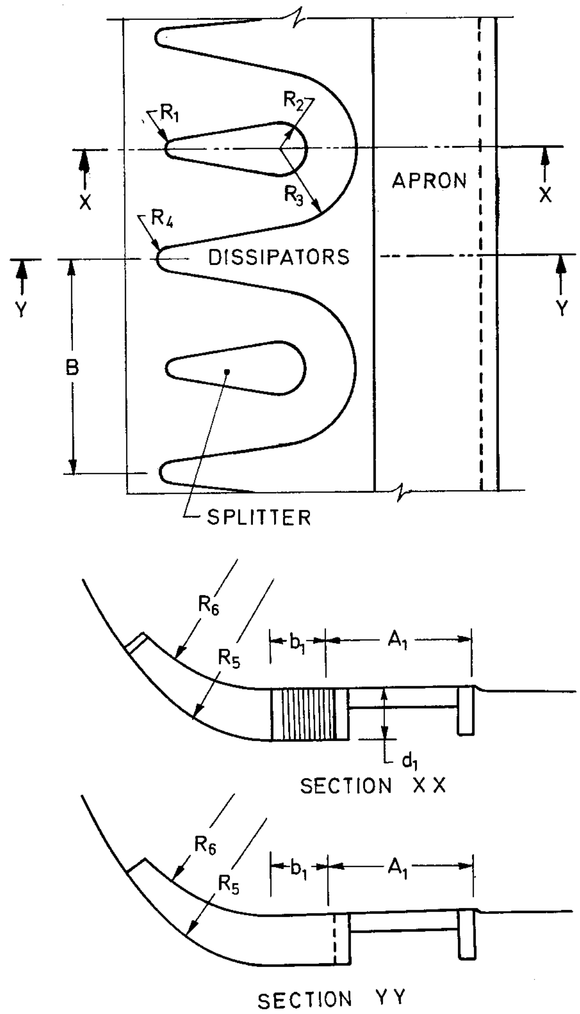


FIG. 16 JET DIFFUSION STILLING BASIN



$R_1 = 0.03$ B $R_2 = 0.13$ B $R_3 = 0.37$ B
$R_4 = 0.03$ B $R_5 = 0.66$ B $R_6 = 0.66$ B
$d_1 = 0.18$ B $A_1 = 0.71$ B $b_1 = 0.25$ B
where B is the bay width

FIG. 17 INTERACTING JET DISSIPATOR

6.1.2 *Bucket Type Energy Dissipators* (*see* IS 7365)

These are of the following three types (*see* IS 7365):

a) Solid roller bucket,
b) Slotted roller bucket, and
c) Ski-jump (or flip or trajectory) bucket.

6.1.3 *Two Stage Energy Dissipator* (*see* Fig. 22)

The design of two-stage energy dissipator is non-conventional as it involves a combination of two energy dissipators. The energy is dissipated in two stages in order to save depth of excavation. Major part of the energy is dissipated in the first stage and the second stage takes care of the residual energy. This is especially suitable in situations when the flow issuing from the energy dissipator is at an angle to the normal river flow in a deep river gorge and the opposite bank in danger of being attacked and also when the return flow may be generated along both sides of the energy dissipator impairing its performance.

7 SELECTION OF TYPE OF ENERGY DISSIPATORS

7.1 No hard and fast criterion can be fixed in selecting a particular type of energy dissipator. The following points may be kept in view while selecting the type of energy dissipators:

a) Frequency and intensity of flood flows;
b) The degree of protection to be provided for very high floods;
c) Type of dam and its spillway;
d) Proximity of power house, tailrace and other structures;
e) Nature of foundations;
f) Velocity and nature of flow;
g) Elevations of tailwater at various discharges;
h) Type and amount of bed material rolling over the spillway;
j) Safety of existing structures downstream; and
k) Any special consideration, such as deep pool in close proximity of dam or its downstream.

7.2 In view of the above, only broad guidelines can be given to select a suitable type of device to be subjected to model studies. The final choice can be made after satisfactory results from model studies are obtained.

7.2.1 *Type of Dam and Its Spillway*

If the dam is an arch dam with a free fall spillway, it should normally be provided with stilling pools of high depths, whereas an earth dam with chute spillway can be provided with a hydraulic jump basin, with or without baffles, or end-sills to suit tailwater rating curves. Similarly, if water flows from a reservoir through a tunnel outlet, the energy can best be dissipated by jet diffusion. For high dams with high tailwater depths, roller buckets may be employed.

7.2.2 *Nature of Foundations*

If the river bed is solid rock, a bucket type of energy dissipator may be most suitably adopted with much lesser length of stilling basin. In case the river bed is softer jointed and fractured rock or alluvial deposit, a long apron with a hydraulic jump type stilling basin with baffles and end-sill may be more suitable.

7.2.3 *Velocity of Flow*

If velocity of flow is high, baffles in the stilling basin cannot be provided.

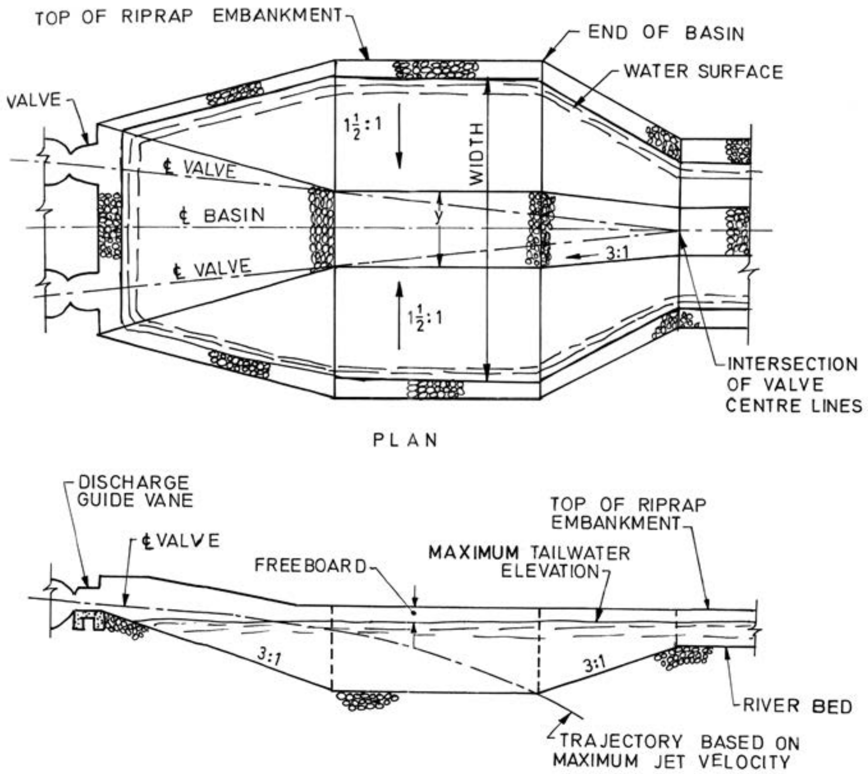


FIG. 18 FREE JET STILLING BASIN

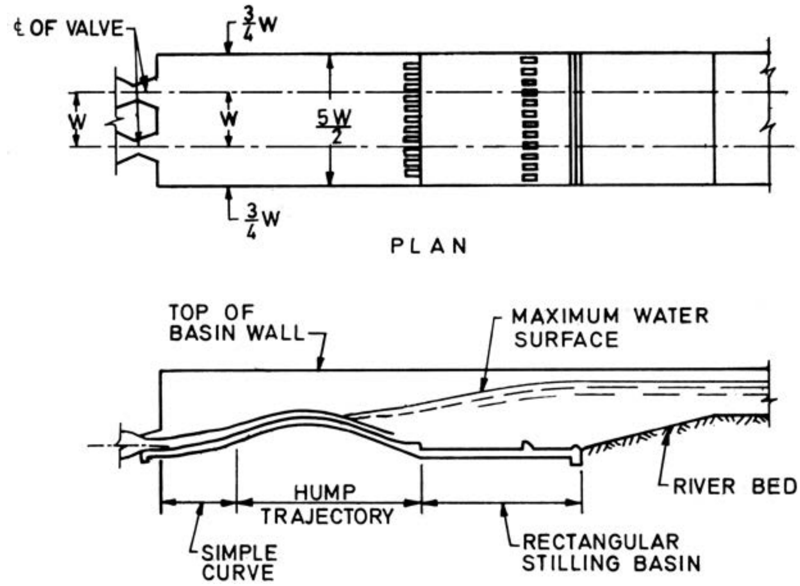


FIG. 19 HUMP STILLING BASIN

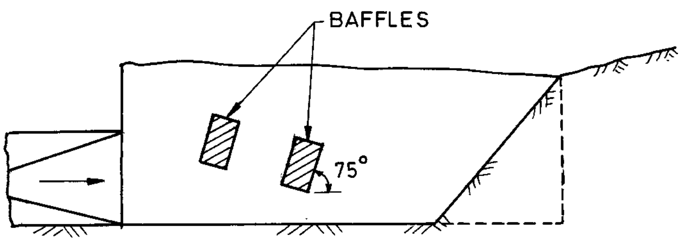


FIG. 20 IMPACT STILLING BASIN WITH INCLINED BAFFLES

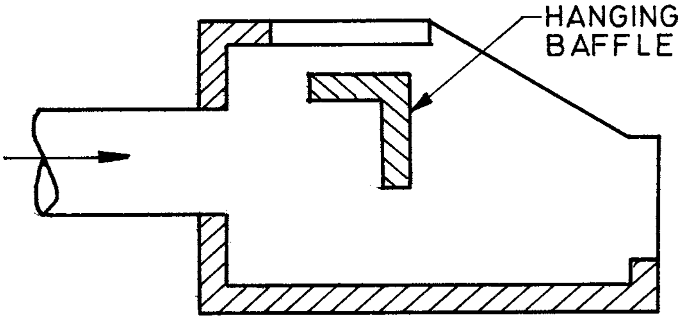
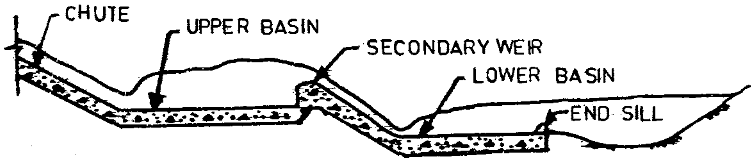
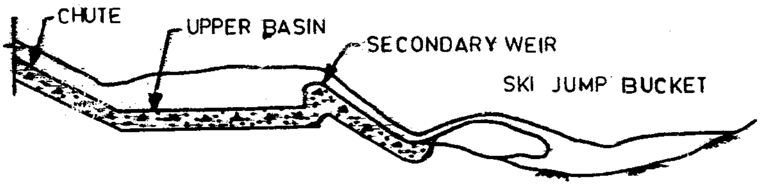


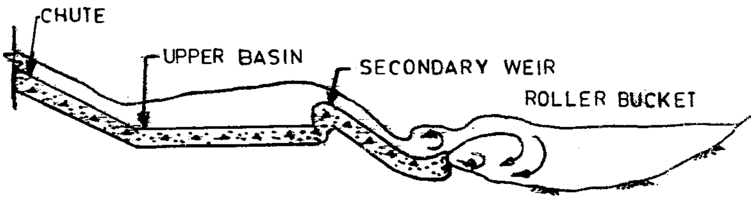
FIG. 21 IMPACT STILLING BASIN WITH HANGING BAFFLE



22A Two Stilling Basin Scheme



22B Stilling Basin and Ski Jump Bucket Scheme



22C Stilling Basin and Roller Bucket Scheme

FIG. 22 TYPES OF TWO STAGE ENERGY DISSIPATORS

7.2.4 *Elevation of Tailwater at Various Discharges*

Accuracy of data in this respect is a pre-requisite for the most efficient and economic type of structure. The jump height curve may be related to the depth-discharge curve in four different ways given at **7.2.4.1** to **7.2.4.4**.

7.2.4.1 *Jump height is always above the tailwater depth*

This means that the depth of flow in the river in the particular section is insufficient for all discharges for the formation of a jump at the toe of the structure. The jump will try to sweep across the apron at a high velocity and attack the bed downstream. The energy dissipation for this case can be achieved in any of the following ways:

a) Lowering the floor level downstream of the dam, so as to make the tailwater depth in the stilling basin equal to the jump height for all discharges. This may lead to three alternatives:
   1) A horizontal floor but depressed below the river bed level,
   2) A depressed floor but rising towards the downstream end; and
   3) A depressed floor but sloping away from the toe of the dam.

b) Stilling basin with baffles or stills at river bed level;
c) Stilling basin with a low subsidiary dam downstream; and
d) Ski-jump bucket.

7.2.4.2 *Jump height is less than the tailwater depth*

With higher depth of tailwater the tendency of the high velocity flow is to dive under the tailwater and travel a long distance along the bottom, forming only a very imperfect jump. The energy dissipation can be done in the following ways:

a) Sloping apron, and
b) Roller bucket type of energy dissipators.

7.2.4.3 *Jump height more than tailwater depth at low discharges and less at higher discharges*

For such a condition, the solution lies in creating artificially enough water depth to make the jump form on the apron at low discharges. The following alternatives can be applied to the problem:

a) Stilling basin with a low secondary dam, and
b) Stilling basin with baffle piers or some form of dentated sill.

7.2.4.4 *Jump height below the tailwater depth at low discharges and above at higher discharges*

The main condition to be met in this case is the provision of sufficient depth of tailwater for the formation of the jump to high flows. Construction of a secondary dam or sloping apron will serve the purpose. A bucket type of energy dissipator can be provided with success if rock below is sound which will act as roller for low discharges and ski-jump at higher discharges.

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This Indian Standard has been developed from Doc No.: WRD 09 (0585).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Published by BIS, New Delhi